Residential Smoke Alarm Project: Sublethal Effects of Irritant and Asphyxiant Gases on Egress Time

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Background
Irritants, Asphyxiants and Egress

- ISO 13571
  - Reduce irritant gas production from burning building materials
- Recent events (9/11)
  - Escape from hazardous situations
  - Residual effects of smoke exposure
- Concentrations below tenability limits

Irritant and Asphyxiant Gas Effects on Egress: Approach

- Create basic escape scenario
- CPSC Human Factors (HF) staff
  - Estimate escape time
  - Quantify physiological effects
- CPSC Health Sciences (HS) staff
  - Non-fire related exposures (CO)
  - Magnitude of physiologic effects
- Estimate change in egress time

Irritant and Asphyxiant Gases

- Asphyxiant Gases
  - Hypoxia
  - Central nervous system depression
  - Cardio-vascular effects
- Effects of irritant gases
  - Important at early stages of fire before massive buildup of asphyxiant and/or HCN
  - Egress maybe sufficiently delayed to allow onset of serious asphyxiant effects

Carbon Monoxide

- CO binds to hemoglobin in blood to produce COHb
  - Interferes with O2 uptake and delivery resulting in oxygen deprivation
  - Blood COHb (%COHb) serves as a useful approximation of CO poisoning severity
    - Generally progressively worsening symptoms with increasing COHb

Carbon Monoxide

- CO poisoning regarded as a continuum of effects
- Serious disorientation and possible loss of consciousness on reaching 30-40% COHb
  - May occur with prolonged elevations of 20-30%
  - Negatively impacts egress time of healthy individuals
- Dependent on time course profile of CO

Carbon Monoxide

- CPSC - Non-fire related exposures from combustion products generally lower than peak levels reached in fire scenarios
- CPSC - Non-fire related CO exposures
  - Combustion products
  - Lower than fires (100’s vs 1000’s ppm)
- Coburn Foster Kane (CFK) equation

Irritant Gases

- Irritants quantified by FTIR
  - HCl, HBr, HF, and NOx
- Health Effects
  - Eye irritation
    - Eye closing, compromised vision, disorientation
  - Upper Respiratory and Lung Irritation
    - Coughing - shortness of breath, body contortions, slowed movement
- Effects of each gas are cumulative

Irritant Gases

- Low concentrations can produce mild effects that may impair an individual's speed of movement through a home
- Moderate concentrations may further decrease escape speed.
  - Some researchers consider irritants to not significantly impair escape and provide a strong stimulus to escape
- High concentrations
  - Severe physiological effects
  - Significant effects on egress speed likely
  - Increased egress time

Egress Coefficient

- Difficulty in quantifying specific escape time
  - Egress time changes with each scenario
  - Dearth of data on irritant effects on egress in home fire scenarios
- Egress coefficient concept of CPSC staff
  - Weighting factor for physiological effects
  - Applied to escape time in drill scenarios

Egress Coefficient

- Calculated based on the concentrations of irritant gases
  - Integrate delay time for various physiological effects
    - Coughing severity, eye irritation, respiratory irritation
  - Multiply clean escape time by the egress coefficient

Egress Coefficient

- Utilize existing exposure limits for irritant gases
  - IDLH, AEGL, EEGL, TLV-TWA, etc.
  - Ambient concentrations in
    - Environment
    - Workplace
  - Emergency situations
    - Low level chronic exposures in homes (e.g., CO from furnaces)
    - Fire scenarios
  - Post-exposure health effects
- Compare gas concentrations in fire to exposure limits

Egress Coefficient

- Integrate exposure limits with health impacts model
  - Quantify effect severity for coughing, eye irritation, respiratory irritation (e.g., mild, moderate, and severe)
  - Estimate magnitude of physical effects of gas concentrations (e.g., mild, moderate, and severe)
  - Magnitude of effects translated into egress coefficient in model

Example

- Basic Case
  - The “drill escape time” is estimated for the best case scenario
    - Lone, healthy young adult with predetermined escape route
    - No attempts to retrieve valuables or other items.
    - No impact from any other physical, chemical, or psychological factors
- Concentration of irritant gases quantified or estimated
  - Gas concentrations used in model to predict severity of physiologic response
  - Response estimations used in model to calculate egress coefficient

Example

- Estimated “basic case” drill escape time is 2 minutes
  - CPSC Human Factors estimates
- Egress coefficient is 1.5
  - Xppm cumulative irritant gas concentration
  - Mild to moderate health effects
- Calculation:
  - 2 minute drill escape time x 1.5 egress coefficient = 3 minute escape time for a given concentration of irritant gas

Conclusions

- CPSC HS and HF to review irritant and asphyxiant gas data for potential effects
- Dearth of available data on irritant effects
- Model for delay includes egress coefficient
- Will compare escape scenarios and potential for incapacitation from effects of combustion gases